Newton 's Experimentum Crucis vs. Goethe's Series of Experiments: Implications for the Underdetermination Thesis

James A. Marcum
Baylor University

In the seventeenth century, Isaac Newton conducted experiments to determine the nature of the relationship between sunlight and colored rays. These experiments are reported in a paper presented at the Royal Society of London and published in its *Transactions*. According to Newton, sunlight is com posed of a "*Heterogeneous mixture of differently refrangible Rays*." The theory, he claimed, is established on a single experiment, an *experimentum crucis*, in which he refracted sunlight with a prism into its color spectrum—each colored ray with a specific angle of refraction. With a second prism, he demonstrated that the refracted rays of color could no longer be dispersed further. Importantly, the crucial experiment permitted Newton to distinguish his theory of light and color from competing theories, such as Descartes' notion of light as rotating globules.

In a critique of Newton's *experimentum crucis*, Johann Wolfgang von Goethe claimed that Newton's theory of color is an artificial construct of the human intellect and is not derived from nature itself. Goethe argued that Newton constructed experiments based on an artificial order rather than on a natural order. The result of Newton's artificial method—based on an *experimentum crucis*—is a distorted view of nature. In contrast, Goethe devised and conducted experiments in which he altered the conditions of the experiments in terms of the prism's refracting angle, the distance from the subject to the prism, and the object viewed. Whereas Newton concluded that colorless sunlight is primary and colored light secondary or illusory, Goethe concluded that color is not simply secondary but primary.

In a well known essay *Der Versuch als Vermittler von Objekt und Subjekt*, Goethe argued that experiments act as mediators between the objective and the subjective. According to Goethe, experiments allow scientists to "re-create natural or artificial phenomena" in an attempt to bridge the gap between their ideas about a natural object and the object itself. As mediators, experiments are the means scientists often use to navigate between how they think nature functions as articulated in their theories and hypotheses (the subjective) and how nature actually functions (the objective). In other words, experiments in general allow scientists to link or connect their epistemic claims—claims that assert something about nature—with the ontological dimension of nature or "the way nature is," especially within the confines of a laboratory experience.

Based on a holistic approach, Goethe pro posed the notion of "series of experiments" as mediators. According to Goethe, an experimental series is "a series of contiguous experiments derived from one another." In other words, the empirical outcome of one series of experiments implies the undertaking of another series. Through sequential empirical implications, series of experiments are derived one from another and thereby act as mediators to link scientific theories and hypotheses about natural phenomena with the experience of those phenomena, especially in the laboratory. The derivation of these experiments through their empirical implications forms a singular experiment and unitary evidence for linking nature and theory. "Studied thoroughly and understood as a whole," concluded Goethe, "these experiments could even be thought of as representing a single experiment, a single piece of empirical evidence."

According to Goethe the series of experiments, as mediator between the subjective and objective, provides "empirical evidence of a higher sort." This notion of higher evidence bridges the gap between the epistemic claims of a theory and the ontological dimension

of nature, through the sequence of empirical implications from one experimental series to the next. Just as in mathematics axioms are connected by their logical implications, so, claimed Goethe, in an analogous but not identical fashion, in experimental science empirical implications connect one experimental series to another: "These pieces of evidence may be expressed in concise axioms and set side by side, and as more of them emerge they may be ordered and related. Like mathematical axioms they will remain unshakable either singly or as a whole." Thus, the greater the number of outcomes from a variety of different experimental series that are contiguously connected and ordered through their empirical implications and that support the relevant theory, the better substantiated it is. Of course, the gap between nature and theory cannot be completely bridged no matter how many contiguously connected experiments are performed, as Goethe recognized, because no experimental evidence captures completely the complexity of causal interactions present in nature.

Goethe's notions of series of experiments as mediator and of higher empirical evidence have important implications for the contemporary philosophical underdetermination thesis. Briefly, the thesis states that experimental evidence is inadequate to choose among competing theories. However, in light of Goethe's notions, empirical evidence can support, to diverse degrees, competing theories because portions of that evidence support each of the competing theories dissimilarly. Although the evidence is shared by the competing theories, it is not quite the same from one researcher or research team to another. Rather, there is generally significant development of empirical evidence as scientists vary the type and increase the number of experiments performed to substantiate or justify a theory.

In light of Goethe's notions of series of experiments and of higher evidence, then, the issues raised by the underdetermination thesis, at least a weaker version of it, are resolved in terms of the higher evidence from serial experimentation in choosing a theory over its competitors. Of course, a stronger thesis of underdetermination remains unresolved since, in principle, an empirically equivalent theory can always be pro posed. Furthermore, analysis of Newton's experiments reveals that his experiments on the nature of light and color also formed a series of experiments, although a limited series, with the generation of higher empirical evidence. For Goethe, "the greatest accomplishments come from those who never tire in exploring and working out every possible aspect and modification of every bit of empirical evidence, every experiment." Only then can scientists choose with confidence, although only provisionally, a theory.